

Postprint of Performance Evaluation of Digital Resources Services in University Libraries Based on Combination Weighting-TOPSIS Method

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Abstract

[Purpose/Significance] To construct a scientific and rational performance evaluation index system for university library digital resources and conduct an empirical evaluation of digital resource service performance in Hunan university libraries using evaluation models, thereby providing a scientific decision-making basis for targeted optimization and improvement measures. [Method/Process] From the three dimensions of input, process, and impact, we construct a performance evaluation index system for university library digital resource services comprising 7 first-level indicators and 19 second-level indicators. On this basis, a combined weighting model integrating the Analytic Hierarchy Process (AHP) from subjective weighting methods and the CRITIC method from objective weighting methods is employed to calculate the combined weights of performance evaluation indicators, and an improved TOPSIS method is further adopted to calculate the performance evaluation values. [Results/Conclusion] The digital resource service capability of Hunan university libraries is highly correlated with their institutional types and exhibits relatively significant differences. Regarding influencing factors of digital resource service performance, university libraries exhibit marked differences in input costs, publicity/training/promotion, and academic output, while differences in overall content, retrieval systems, supporting services, and utilization are relatively minor. In the future, various types of university libraries in Hunan should not only optimize weak links in digital resource services but also systematically and comprehensively enhance library digital resource service performance from a multi-dimensional perspective of input, process, and impact.

Full Text

Performance Evaluation of University Library Digital Resource Services Based on Combined Weighting-TOPSIS Method

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Abstract

[Purpose/Significance] This study constructs a scientific and rational performance evaluation index system for university library digital resources and applies the evaluation model to conduct an empirical assessment of digital resource service performance in Hunan province university libraries, providing a scientific decision-making basis for targeted optimization and improvement measures.

[Method/Process] From the three dimensions of input, process, and impact, we construct a performance evaluation index system for university library digital resource services comprising 7 primary indicators and 19 secondary indicators. Building upon this foundation, we employ a combined weighting model that integrates the Analytic Hierarchy Process (AHP) as a subjective weighting method and the CRITIC method as an objective weighting method to calculate the combined weights of performance evaluation indicators. We further adopt an improved TOPSIS method to calculate the performance evaluation values of university library digital resource services.

[Result/Conclusion] The digital resource service capabilities of Hunan province university libraries are highly correlated with their institutional types and exhibit significant differences. In terms of influencing factors, substantial disparities exist among university libraries in input costs, publicity/training/promotion, and academic output, while differences in overall content, retrieval systems, supporting services, and utilization are relatively smaller. Going forward, Hunan university libraries of various types should not only address weaknesses in their digital resource services but also systematically enhance service performance from the multi-dimensional perspective of input, process, and impact.

Keywords: university libraries; digital resource service; performance evaluation; combined weighting; TOPSIS

1. Introduction

With the development of information and communication technologies, library users, environments, resources, tools, and services have undergone fundamental transformations. Digital resources have become crucial collection resources in the big data era. In China, university library funding has maintained stable growth in recent years, with increasingly rich digital resource collections, rising procurement costs, and growing digitalization levels. Digital resource services have become the main content of university libraries. Consequently, a series of practical questions have drawn widespread attention from library scholars both domestically and internationally: How is the quality of these costly digital resources? Are they being used effectively? How can we scientifically measure and comprehensively evaluate their service performance?

Digital resource service performance evaluation involves making objective, fair, and accurate judgments and analyses of digital resource service efficiency and effectiveness based on objective facts and data through scientific methods [?]. Since the mid-1990s, as digital resources and services have accounted for an increasing proportion of library operations, related issues have attracted significant attention from international library scholars, with research on digital resource evaluation gradually expanding. In 2006, J. Luther conducted pioneering research on electronic journal usage evaluation, particularly regarding statistical data [?]. In 2011, Y. Noh employed DEA-CCR and DEA-BCC models to assess the resource efficiency of digital libraries in Korean university libraries [?]. Additionally, international library organizations and academic groups have launched various research projects on digital resource utilization and benefit evaluation. In 2000, the Association of Research Libraries (ARL) initiated the “E-metrics” project to develop scientific evaluation indicator systems for systematic digital resource assessment [?]. Currently, this project continues to support the development of an independently and widely accepted “implementation code” for networked database usage statistics called COUNTER. The European Commission-funded EQUINOX project, aimed at researching performance evaluation methods and operational frameworks for information services in networked environments, formed a 14-indicator library electronic service performance evaluation system in 2000 [?].

Domestic research on library digital resource evaluation began in the early 21st century. In 2004, the Ministry of Education’s University Library Work Committee stated that “incorporating digital resource measurement and statistics into the unified statistical work and evaluation of university library literature resource construction is entirely necessary,” and clearly defined digital resource conversion methods in the “Guidelines for Digital Resource Measurement in University Libraries,” providing useful guidance for evaluating digital resource construction [?]. In 2014, Li Yingying et al. proposed a knowledge service diamond system and digital resource service diamond system from the perspective of knowledge service processes, constructing an evaluation index system for university library digital resources and employing the Analytic Hierarchy Process to

assign weights to indicators at all levels [?]. In 2015, Liang Ru et al. used a comprehensive evaluation method combining factor analysis, cluster analysis, and entropy method to evaluate the digital resource comprehensive service capabilities of 30 university libraries from four dimensions: funding/personnel/facility input, scale/growth, information service output, and teaching/research output [?].

2. Construction of the Performance Evaluation Indicator System

Evaluating the performance of university library digital resource services requires first establishing an evaluation indicator system. Based on a review of international frameworks—including the European Commission’s 1998 EQUINOX performance indicator system for electronic library services [?], ARL’s 2000 E-Metrics project, and ISO 2789 (2003) Appendix A [?—and domestic research by scholars such as Liang Ru et al. [?] and Xiao Long et al. [?], we analyze the connotation and characteristics of university library digital resource services in the digital knowledge environment. Drawing on the classic multi-dimensional logical model framework and concepts of international public project performance evaluation, we construct a performance evaluation index system from three dimensions: input, process, and impact.

2.1 Input Dimension

The input dimension indicators primarily relate to funding investment and publicity/training/promotion of digital resource services. This dimension includes two primary indicators: “input cost” and “publicity, training, and promotion.”

2.2 Process Dimension

The process dimension indicators primarily relate to service capabilities throughout the user experience with digital resources. This dimension includes three primary indicators: “overall resource content,” “retrieval system,” and “supporting services.”

2.3 Impact Dimension

The impact dimension indicators primarily relate to utilization and output impact of digital resource services. This dimension includes two primary indicators: “utilization situation” and “academic output.”

Based on these primary indicators, we further design 19 secondary indicators, forming the final performance evaluation index system shown in Table 1 .

3. Performance Evaluation Model Based on Combined Weighting-TOPSIS Method

3.1 Combined Weighting of Performance Evaluation Indicators

3.1.1 Standardization of Raw Data Assume there are m university library digital resource service performance evaluation objects and n evaluation indicators. Let r'_{jk} represent the value of the k -th indicator for the j -th evaluation object ($j = 1, 2, \dots, m; k = 1, 2, \dots, n$). The raw data decision matrix R' is:

$$R' = \begin{bmatrix} r'_{11} & r'_{12} & \cdots & r'_{1k} \\ r'_{21} & r'_{22} & \cdots & r'_{2k} \\ \vdots & \vdots & \ddots & \vdots \\ r'_{j1} & r'_{j2} & \cdots & r'_{jk} \end{bmatrix}_{m \times n}$$

Based on the raw data decision matrix, indicators are classified as positive or negative indicators. We apply linear function normalization to homogenize and normalize the attribute matrix, constructing the standardized matrix $R = [r_{jk}]_{h \times i}$ ($1 \leq j \leq h, 1 \leq k \leq i$), where r_{jk} represents the standardized value of the k -th digital resource service performance indicator for the j -th evaluated university library.

3.1.2 CRITIC Method for Objective Weight Calculation The CRITIC method is an objective weighting approach that determines indicator weights through contrast intensity and conflict. Let E_k represent the information content of the k -th evaluation indicator, where f_{kh} denotes the correlation coefficient between indicators k and h , and s_k represents the dispersion of indicator k across different evaluation objects m , expressed as standard deviation. E_k is calculated as:

$$E_k = s_k \sum_{h=1}^n (1 - f_{kh}) \quad (k = 1, 2, \dots, n) \quad (1)$$

In formula (1), a larger E_k indicates greater information content and greater importance of the k -th indicator. The objective weight calculated by the CRITIC method is:

$$\delta_k = \frac{E_k}{\sum_{k=1}^n E_k} \quad (k = 1, 2, \dots, n) \quad (2)$$

3.1.3 AHP Method for Subjective Weight Calculation The Analytic Hierarchy Process is a subjective weighting method that decomposes decision elements into hierarchical structures of goals, criteria, and alternatives. To determine the indicator system weight set, we: (1) Establish a hierarchical structure model based on the designed evaluation index system, with primary indicators

as the criterion layer and secondary indicators as the scheme layer; (2) Construct judgment matrices for each hierarchical level; (3) Form an expert group of 20 library science professionals and faculty (primarily library and information science backgrounds, including university library directors and professors) who conduct pairwise comparisons using a 1-9 scale; (4) Apply the averaging method for normalization, following Li Yingying et al. (2014) [?], to obtain judgment matrix M and calculate subjective weights γ_k ; (5) Compute the maximum eigenvalue and corresponding eigenvector for each judgment matrix and conduct consistency tests. If the test passes, the normalized eigenvector represents the weight vector.

3.1.4 Calculation of Combined Weights When the ranking of weighting results from the two methods is inconsistent, linear weighting is used to calculate combined weights. When rankings are consistent, the arithmetic average method suffices to obtain satisfactory combined weights w_k :

$$w_k = \frac{\delta_k + \gamma_k}{\sum_{k=1}^n (\delta_k + \gamma_k)} \quad (3)$$

To verify the rationality of combined weights, we use the Spearman rank correlation coefficient for consistency testing:

$$Q_s = 1 - \frac{6 \sum_{k=1}^n d_k^2}{n(n^2 - 1)} \quad (4)$$

where Q_s is the rank correlation coefficient ($Q_s \in [-1, 1]$). Values approaching 1 indicate higher consistency between the two weighting methods. $d_k = (\delta_k - \gamma_k)$ represents the rank difference, and n is the number of indicators.

3.2 TOPSIS Method for Performance Evaluation

TOPSIS ranks alternatives based on their proximity to ideal solutions, identifying the optimal solution that is farthest from the negative ideal solution and closest to the ideal solution [?]. This approach objectively extracts information from sample data while avoiding reliance on subjective judgment required by multi-linear evaluation methods. The results are interpretable and facilitate comparative analysis.

Using the combined weights from above, we apply an improved TOPSIS method:

- (1) **Construct the weighted normalized matrix:** Combining the standardized matrix R with weight vector W from formula (3):

$$Y = R \times W = \begin{bmatrix} r'_{11} \times w_1 & r'_{12} \times w_2 & \cdots & r'_{1k} \times w_k \\ r'_{21} \times w_1 & r'_{22} \times w_2 & \cdots & r'_{2k} \times w_k \\ \vdots & \vdots & \ddots & \vdots \\ r'_{j1} \times w_1 & r'_{j2} \times w_2 & \cdots & r'_{jk} \times w_k \end{bmatrix}_{m \times n} = \begin{bmatrix} y_{11} & y_{12} & \cdots & y_{1k} \\ y_{21} & y_{22} & \cdots & y_{2k} \\ \vdots & \vdots & \ddots & \vdots \\ y_{j1} & y_{j2} & \cdots & y_{jk} \end{bmatrix} \quad (5)$$

(2) **Determine ideal and negative ideal solutions:**

$$Y^+ = \{\max(y_{j1}, y_{j2}, \dots, y_{jk})\} \quad (6)$$

$$Y^- = \{\min(y_{j1}, y_{j2}, \dots, y_{jk})\}$$

(3) **Calculate distances to ideal solutions:** Using Euclidean distance:

$$S_j^+ = \sqrt{\sum_{k=1}^n (y_{jk} - y_k^+)^2}, \quad j = 1, 2, \dots, m \quad (7)$$

$$S_j^- = \sqrt{\sum_{k=1}^n (y_{jk} - y_k^-)^2}, \quad j = 1, 2, \dots, m$$

(4) **Calculate relative closeness coefficient:**

$$A_j = \frac{S_j^-}{S_j^+ + S_j^-}, \quad j = 1, 2, \dots, m \quad (8)$$

The relative closeness coefficient A_j represents the comprehensive performance value of the j -th university library's digital resource services. Larger A_j values indicate better performance. The sample libraries can then be ranked accordingly.

4. Empirical Study of Hunan University Libraries

4.1 Sample Selection and Data Sources

We selected 10 Hunan universities as research samples: the top 5 first-tier universities (out of 10) and top 5 second-tier universities (out of 23) based on 2016 Hunan university rankings. Data sources include: the Ministry of Education's University Library Work Committee real-time database (<http://libdata.scal.edu.cn/login.html>), National Social Science Statistics Compilation, field surveys, emails, and telephone consultations. Resource content data (A_3) were obtained through library website visits and publisher interviews. Retrieval system data (A_4) were collected via questionnaires using a 9-point Likert scale, with qualitative indicators normalized using the averaging

method. Publicity/training/promotion (A_2) and supporting services (A_5) data were obtained through field interviews, emails, and telephone consultations.

After obtaining raw data, we classified indicators as positive or negative, applied linear function normalization for homogenization, and constructed the standardized matrix $R = [r_{jk}]_{h \times i}$.

4.2 Determination of Indicator Weights

The CRITIC and AHP methods yielded identical ranking orders for indicator weights δ_k and γ_k , allowing direct calculation of combined weights w_k using the arithmetic average method (formula 3). The combined weights for Hunan university libraries are shown in Table 2. Consistency testing using the Spearman rank correlation coefficient (formula 4) yielded $Q_s = 0.99998$, nearly approaching 1, indicating high consistency between the two methods and confirming the rationality of the combined approach.

Table 2 reveals that among primary indicators, the top three combined weights are utilization situation (A_6 , 0.2172), input cost (A_1 , 0.1799), and academic output (A_7 , 0.1622), indicating that input and impact are key evaluation focuses. Among secondary indicators, the top five are: number of papers (A_{71} , 0.0988), digital resource procurement fee (A_{11} , 0.0942), retrieval times (A_{63} , 0.0920), downloads (A_{62} , 0.0764), and number of patents (A_{72} , 0.0634). These span all three dimensions, with impact indicators being most numerous. The procurement fee largely determines resource scale, while papers and patents directly reflect research output, and retrieval times/downloads reflect usage efficiency. These weight results align with actual library service conditions and scientifically reflect evaluation priorities.

4.3 Performance Score Calculation

Substituting standardized values r_{jk} and combined weights w_k into formulas (7) and (8) yields comprehensive performance values A_j for each sample library, shown in Table 3.

The ranking from highest to lowest performance is: Central South University, Hunan University, Hunan Normal University, Changsha University of Science & Technology, Xiangtan University, Hunan University of Technology, Jishou University, Hunan University of Commerce, Hunan First Normal University, and Hunan University of Finance and Economics.

To identify performance similarity patterns, we applied K-means clustering to the comprehensive performance values using SPSS 19, classifying the 10 libraries into four types: Type I ($A \in [0.7121, 1)$) = high performance; Type II ($A \in [0.4043, 0.7121)$) = relatively high performance; Type III ($A \in [0.2243, 0.4043)$) = medium performance; Type IV ($A \in [0, 0.2243)$) = low performance.

4.4 Performance Analysis

Type I (Central South University) achieved a comprehensive performance score of 0.7121, ranking first in all primary indicators, particularly in supporting services (A_5) and academic output (A_7). In 2016, its digital resource procurement reached ¥18.864 million with a 2.1% average annual increase (2012-2016). Its e-journal and e-book subject coverage reached 99%, with average data update time of 15 days, monthly average retrieval times of 1,426.1, 3,595 published papers, and 1,318 patents—all significantly higher than other Hunan universities. This demonstrates Central South University's substantial advantages as a key comprehensive university in funding, utilization, and research output.

Type II (Hunan University, Hunan Normal University, Changsha University of Science & Technology) scored 0.5217, 0.4305, and 0.4068 respectively. These universities show minimal gaps with Central South University in process indicators (retrieval system A_4 and supporting services A_5) but lag considerably in impact indicators (utilization A_6 and academic output A_7). For instance, their 2016 monthly average retrieval times were 910.5, 891.3, and 912.3 respectively, with paper outputs of 1,663, 1,658, and 976—significantly lower than Central South University. These Type II libraries should focus on improving output conversion rates.

Type III (Xiangtan University, Hunan University of Technology, Jishou University, Hunan University of Commerce) scored 0.3555, 0.3433, 0.2896, and 0.2841 respectively. These institutions show significant gaps in input and process dimensions, particularly in publicity/training/promotion (A_2) and overall resource content (A_3). As universities with distinctive disciplinary features, they need to enhance overall resource scale and innovative service capacity.

Type IV (Hunan First Normal University and Hunan University of Finance and Economics) scored 0.2144 and 0.2055 respectively. These specialized institutions, constrained by their disciplinary scope, show low performance across all three dimensions and require systematic improvement in service capability and efficiency.

To further identify key influencing factors, we conducted K-means clustering on primary indicator performance scores, counting how many universities achieved Type II or above performance for each indicator (Figure 2 [Figure 2: see original paper]). Indicators A_1 , A_2 , and A_7 (input and impact categories) achieved Type II+ performance fewer than 4 times each (2, 4, and 3 times respectively), while A_3 , A_4 , A_5 , and A_6 (process categories) achieved this level 5, 7, 6, and 8 times respectively. This indicates that while Hunan university libraries have improved process dimensions (content, retrieval systems, supporting services, utilization), significant differences remain in input costs, publicity/training/promotion, and academic output—these represent key areas for future optimization.

5. Conclusions and Recommendations

Given the numerous factors affecting digital resource service performance, the difficulty of indicator selection and quantification, and the dynamic complexity of service activities, this study constructs a performance evaluation index system from input, process, and impact dimensions. The combined AHP-CRITIC weighting method overcomes limitations of single approaches, enhancing representativeness, consistency, and scientific rationality. The improved TOPSIS model provides an objective evaluation framework. Empirical analysis of 10 Hunan university libraries reveals that service capability is highly correlated with institutional type, with significant performance differences. Key influencing factors include input costs, publicity/training/promotion, and academic output, while process dimensions show smaller variations. Based on these findings, we propose three-dimensional recommendations:

5.1 Input Dimension

Libraries should increase digital resource investment and strengthen publicity/training/promotion through professional subject librarians. Except for Central South University, all libraries should increase investment and integration, prioritizing digital resource construction. Introducing Patron-Driven Acquisitions (PDA) based on user demand reports, collection policies, and expert opinions can optimize procurement strategies. Simultaneously, cultivating comprehensive, professional subject librarians can enhance user interaction, accelerate demand acquisition, and improve training effectiveness while analyzing, selecting, and processing dispersed resources to provide knowledge-based information services.

5.2 Process Dimension

Libraries should enhance inter-library resource sharing cooperation and establish efficient digital resource service platforms using artificial intelligence. While Hunan libraries have made progress in content, retrieval systems, and supporting services, future optimization should leverage resource, talent, and IT advantages to build network platforms and strengthen cooperation. Building upon the Hunan Academic Digital Library alliance, libraries should develop cooperation mechanisms with domestic literature alliances, databases, and international institutions to promote co-construction, sharing, and integrated development. AI-optimized retrieval algorithms and unified user authentication modules can enable intelligent unified retrieval of heterogeneous data, creating a unified digital resource service platform [?].

5.3 Impact Dimension

Libraries should improve output conversion rates and enhance innovative service capabilities to increase resource utilization benefits. Significant output differences exist, particularly for Type III and IV institutions. These libraries

should build characteristic databases (faculty papers, teaching references, research achievements, specialized databases) and create “information-learning-academic” integrated shared spaces to deeply mine and extract relevant and cross-disciplinary resources. By enriching innovative service connotations and providing comprehensive information and knowledge service systems, libraries can maximize digital resource value and effectively improve utilization benefits.

References

- [?] Liang Ru, Li Jianxia, Liu Ying, et al. Evaluation of comprehensive service capability of digital resources in university libraries [?]. *Journal of Academic Libraries*, 2015(2): 38-46.
- [?] Xiao Long, Zhang Yuhong. Preliminary study on establishing an evaluation index system for electronic resources [?]. *Journal of Academic Libraries*, 2002(3): 35-42.
- [?] Summerfield M M, Carol A, Kantor P B. Online books at Columbia: early findings on use, satisfaction and effect [?]. *Technology and Scholarly Communication*, 1999, 25(3): 282-308.
- [?] Luther J. White paper on electronic journal usage statistics [?]. [2019-02-20]. <http://www.clir.org/PUBS/report/pub941contentits.html>.
- [?] Noh Y. Evaluation of the resource utilization efficiency of university libraries using DEA techniques and a proposal of alternative evaluation variables [?]. *Library hi tech*, 2011, 29(4): 97-724.
- [?] Xu Ge. Research on electronic resource performance evaluation in university libraries [?]. Chengdu: Southwest Jiaotong University Press, 2008.
- [?] Dickinson G K. Selection and evaluation of electronic resources [?]. Englewood, CO: Libraries Unlimited, Inc, 1994.
- [?] Gregory V L. Selecting and managing electronic resource: a how-to-do-it manual for librarians [?]. New York: Neal-Schuman, 2000.
- [?] Duy J, Vaughan L. Usage data for electronic resources: a comparison between locally collected and vendor-provided statistics [?]. *The journal of academic librarianship*, 2003, 29(1): 16-22.
- [?] Ministry of Education University Library and Information Work Steering Committee, China Academic Library & Information System. Guidelines for digital resource measurement in university libraries (2004 edition) [?]. *Journal of Academic Libraries*, 2004(3): 90, 89.
- [?] Li Yingying, Wang Huanjing, Zheng Chunhou. Fuzzy comprehensive evaluation of university library digital resource services based on quasi-entropy weight model [?]. *Library Tribune*, 2014(5): 17-78.

[?] Pu Xiaoge, Qiao Yaming, Hu Yamin. Research on performance evaluation model and empirical study of electronic resources in university libraries based on network analysis method [?]. *Journal of Academic Libraries*, 2014(4): 41-49.

[?] Zhou Qingmei, Wang Keqi. Research on fuzzy neural network evaluation of library digital resource service performance [?]. *Information Science*, 2015(2): 41-45.

[?] Hua Xiuling. Research on performance evaluation of university library digital resource services from multi-dimensional perspective [?]. *Library Theory and Practice*, 2018(11): 102-104.

[?] Guan Fang, Lin Qiang, Yin Jin. Research on user adoption model of university library digital resources: a case study of Xidian University Library [?]. *Journal of the China Society for Scientific and Technical Information*, 2015(2): 203-212.

[?] Pu Xiaoge, Hu Yamin. Analysis of multi-indicator comprehensive evaluation methods for library electronic resource performance [?]. *Library and Information Service*, 2013(4): 139-146.

[?] Xu Jianbing. Dilemmas and countermeasures in library digital resource construction [?]. *Journal of Library Science*, 2018(4): 45-49.

[?] Qian Weiwei, Feng Zhiying. Experimental research on quantifying functional user experience of library information services [?]. *Library and Information Service*, 2019, 63(6): 52-64.

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